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Note on the effect of horizontal gradients for nadir-viewing microwave and infrared sounders

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SUMMARY

Passive microwave and infrared nadir sounders such as the Advanced Microwave Sounding Unit-A (AMSU-A) and the Atmospheric InfraRed Sounder (AIRS), both flying on NASA's EOS polar-orbiting Aqua satellite, provide information about vertical temperature and humidity structure that is used in data assimilation systems for numerical weather prediction and climate applications. These instruments scan across track so that, at the satellite swath edges, the satellite zenith angles can reach ∼60°. The emission path through the atmosphere as observed by the satellite is therefore slanted with respect to the satellite footprint's zenith. Although radiative transfer codes currently in use at operational centres use the appropriate satellite zenith angle to compute brightness temperature, the input atmospheric fields are those from the vertical profile above the centre of the satellite footprint. If horizontal gradients are present in the atmospheric fields, the use of a vertical atmospheric profile may produce an error.

This note attempts to quantify the effects of horizontal gradients on AIRS and AMSU-A channels by computing brightness temperatures with accurate slanted atmospheric profiles. We use slanted temperature, water vapour, and ozone fields from data assimilation systems. We compare the calculated slanted and vertical brightness temperatures with AIRS and AMSU-A observations. We show that the effects of horizontal gradients on these sounders are generally small and below instrument noise. However, there are cases where the effects are greater than the instrument noise and may produce erroneous increments in an assimilation system. The majority of the affected channels have weighting functions that peak in the upper troposphere (water-vapour-sensitive channels) and above (temperature-sensitive channels) and are unlikely to significantly impact on tropospheric numerical weather prediction. However, the errors could be significant for other applications such as stratospheric analysis. Gradients in ozone and tropospheric temperature appear to be well captured by the analyses. In contrast, gradients in upper stratospheric and mesospheric temperature as well as upper-tropospheric humidity are less well captured. This is likely due in part to a lack of data to specify these fields accurately in the analyses. Advanced sounders, like AIRS, will help to better specify these fields in the future.

KEYWORDS: AIRS AMSU Assimilation Azimuth angle Radiances Satellite

1. INTRODUCTION

The Atmospheric Infra-Red Sounder (AIRS) and the Advanced Microwave Sounding Unit-A (AMSU-A) (Aumann *et al.* 2003) are nadir-viewing passive sounders currently flying on the National Aeronautics and Space Administration's (NASA) Earth Observing System (EOS) polar-orbiting Aqua platform. AMSU-A also flies on the National Oceanic and Atmospheric Administration (NOAA) Polar Orbiting Environmental Satellites along with the High-resolution InfraRed Sounder (HIRS). These and other similar sounders are the primary satellite instruments used in atmospheric data assimilation systems (DASs) for numerical weather prediction and the production of climate datasets.

Fast radiative transfer models are used to compute brightness temperatures from background fields in a DAS. Analysis increments are then generated based on the difference between the observed and the computed brightness temperatures. The effects of so-called limb-brightening or limb-darkening across a scan line for an instrument on a polar-orbiting satellite are accounted for in the radiative transfer model by using an appropriate satellite zenith angle. However, the input atmospheric profile is usually the vertical one above the satellite footprint centre. The correct atmospheric profile should account for the fact that the emission path through the atmosphere is slanted with respect to the footprint zenith. If horizontal gradients are present, an error may occur if the vertical atmospheric path is used.

Horizontal gradient effects are a well-known problem for limb-viewing sounders. For example, gradient effects were shown to be important for the limb-viewing Global Positioning Satellite Radio Occultation sounding technique (e.g. Poli 2004; Poli and Joiner 2004).

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